Active Project (2014 - 2023)

Mars OXygen ISRU Experiment Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

The Mars Oxygen ISRU Experiment (MOXIE) will be the first in-situ resource utilization (ISRU) technology demonstration on Mars. Competitively selected in 2014, MOXIE will fly with the Mars 2020 mission in 2020, to land on Mars in 2021. Sponsored by HEOMD and the Space Technology Mission Directorate (STMD), MOXIE will utilize solid oxide electrolysis to process Mars' CO_2 atmosphere to produce O_2. MOXIE will be a critical first step in long-duration mission architectures that would require use of local resources to reduce risk and control cost. By partnering with Science Mission Directorate on the Mars 2020 mission, human exploration leverages existing investments in the Mars program while advancing a key technology for NASA.

ANTICIPATED BENEFITS

To NASA funded missions:

A key element of NASA's plans to send humans to Mars is the ability to utilize resources at the destination; this will reduce mass launched from Earth and increase mission resiliency.

To NASA unfunded & planned missions:

Once demonstrated on Mars, incorporation of ISRU technologies in future missions will be key to realizing the vision of a sustainable and resilient space exploration architecture. ISRU is expected to play a key role in NASA's expansion beyond low-Earth orbit. For example, future crewed missions will be enabled by use of in-situ resources to produce oxygen for propellant and other consumables.

To the commercial space industry:

By flight qualifying ISRU, NASA supports the development of a new technology readily available for use by commercial resource prospecting missions. This can create new markets for commercial missions anywhere in the Solar System.

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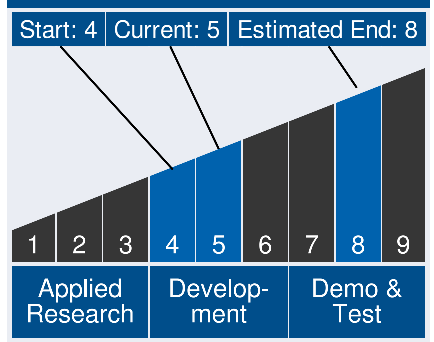
Technology Maturity



Management Team

Program Director:

- Jason Crusan

Program Executive:

- Victoria Friedensen

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To the nation:

This technology can support the nation's goals for human long-term space exploration and the development of new markets and destinations.

DETAILED DESCRIPTION

Experiment objectives are to intermittently operate an oxygen production plant on Mars across a range of diurnal conditions during the primary mission year and producing at least 20g of O_2 per hour with 99.6% purity. The technology will demonstrate resilience with respect to dust and other environmental challenges and will return performance parameter data that are critical to the design of a full-scale system.

MOXIE consists of a CO_2 acquisition system (a scroll pump) and a solid oxide electrolysis (SOXE) system to process the atmosphere producing O_2. O_2 will be processed on a batch basis as rover resources allow but of sufficient amounts to test system resiliency. By monitoring the production rate, power usage, and other performance characteristics of the system, MOXIE will provide an assessment of the prospects for extension to a full-scale system in support of a human mission.

Mars atmosphere enters the system through an inlet valve and dust is filtered out. A scroll pump delivers up to 50 g/hour of atmosphere to the SOXE subsystem. The Mars atmosphere is processed as follows: the SOXE is warmed to 800 C; the pump is started and the filtered air will flow continuously at >1 torr to the SOXE. The O_2 and CO are separated and the flow rate is measured. The O_2 and CO are vented out the side of the rover.

Management Team *(cont.)*

Project Manager:

- Jeffrey Mellstrom

Principal Investigator:

- Michael Hecht

Technology Areas

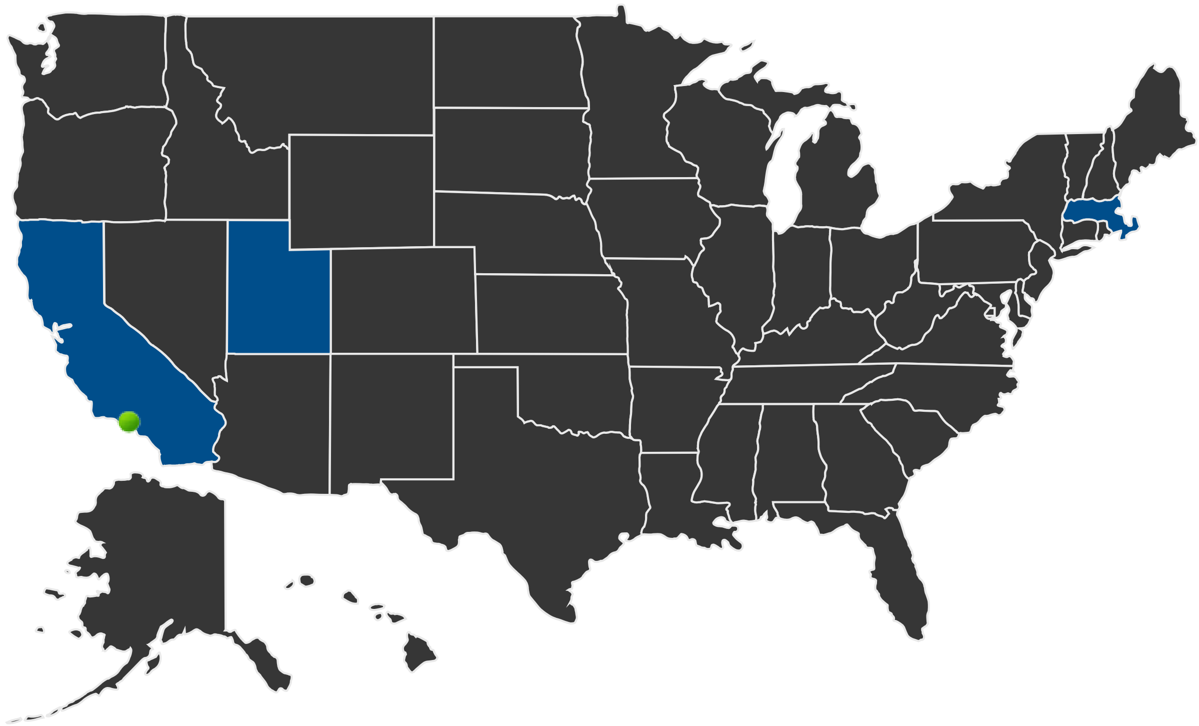
Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└ Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  └ Air Revitalization (TA 6.1.1)
    └ CO2 Reduction (TA 6.1.1.2)

Secondary Technology Area:
Space Power and Energy Storage (TA 3)

Additional Technology Areas:
Human Exploration Destination Systems (TA 7)
└ In-Situ Resource Utilization (TA 7.1)

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Supporting Centers:

- Jet Propulsion Laboratory

Other Organizations Performing Work:

- Ceramatec, Inc. (Salt Lake City, UT)
- Columbia University, New York
- Massachusetts Institue of Technology (Cambridge, MA)

Contributing Partners:

- Imperial College London
- University of Copenhagen

DETAILS FOR TECHNOLOGY 1

Technology Title

Solid Oxide Electrolysis (SOXE) for Processing Mars Atmosphere

Technology Description

This technology is categorized as a hardware subsystem for unmanned spaceflight

The ability to manufacture resources on other solar system bodies is key to future exploration architectures. MOXIE includes the Solid OXide Electrolysis (SOXE) subsystem that will manufacture O_2 from Mars CO_2 atmosphere. As a technology demonstration, the SOXE will be operated intermittently during the Mars 2020 mission's prime mission year and will produce at least 20 grams of O_2 at >99.6% purity. The SOXE subsystem is designed for resilience with respect to dust and other environmental challenges. Instrumentation on the SOXE will return performance parameters that will be critical to the design of a full-scale system.

The SOXE is heated to 800^{o}C to thermodynamically optimize the CO_2 to be converted and to reduce the amount of CO that could be produced and lead to carbon production (coking) in the subsystem. The system is very efficient as the O_2 is produced and separated simultaneously during SOXE operation and requires no additional reactants.

The electrochemical segments within each cell of the SOXE stack are the cathode, the electrolyte and the anode. The CO_2 flows over the catalyzed cathode surface and dissociates into a CO molecule and an O atom. The oxygen atom is subsequently reduced, via the electrical current applied to the SOXE stack to an oxide ion that is then electrochemically driven through the solid oxide electrolyte to the anode. In the anode, the oxide ion is oxidized again, closing the electrical circuit, and combines with another oxygen atom to form O_2 that is released from the anode cavity. The O_2 production rate is determined by the electrical current and the CO_2 flow.

The SOXE stack will be comprised of one mechanical stack separated into two 5-cell electrically-coupled stacks. CO_2 flow, O_2 production, pressure and temperature will be monitored.

Capabilities Provided

The SOXE architecture is scalable to human-scale production rates and ground-based prototypes are robust enough to be considered for Mars exploration uses.

Potential Applications

Potential applications include atmospheric processing on Mars to produce consumable oxygen for propellant production and human use. Solid-oxide electrolysis could also be applicable to oxygen manufacture in spacecraft and in processing water harvested from airless bodies such as the Moon. SOXE also has great potential utility for fuel cells, followed by emphasis on H2 production for a hydrogen economy. Architectures have been developed for compactly packaging stacks of cells, although seals and interconnects remain a challenge.

Performance Metrics

Metric	Unit	Quantity
Production rate	g/hr	20
O2 Purity		99.6%